PINE LAKE

Alberta

ENVIRONMENT
Water Quality Control Branch
Pollution Control Division

89-06095/

Lakes attract people. And people want to know why "their" lake is the way it is — why is it so green in July? Is the water quality really deteriorating? How do our activities affect the lake?

This brochure, one of a series on Alberta's lakes, attempts to answer these questions by presenting findings of water quality studies conducted by the Water Quality Control Branch of Alberta Environment.

As you read through the brochure, you may find you have questions about the concepts and illustrations. At the end is a section called **Explanation of Lake Characteristics.** Refer to this for further interpretation.

Brochures are available for the following lakes:

Sandy Lake	Pine Lake	Lac La Biche
Lac La Nonne	Garner Lake	Nakamun Lake
Wizard Lake	Skeleton Lake	Wabamun Lake

Pine Lake is an attractive, popular lake located about 40 kilometers southeast of Red Deer. There are several resort facilities on the lake with campgrounds and boat access. A government picnic site with a boat launch is situated at the north end of the lake south of a large commercial resort.

Fishing for northern pike (jackfish) and yellow perch is usually good. Walleye (pickerel) also inhabit the lake. Pine Lake is not fished commercially.

As the depth contour map shows, Pine Lake is long and narrow. Its greatest depth, 12 m (40 feet), is located near the southern end. The lake's outflow, called Ghostpine Creek, flows southeast to join the Red Deer River near Drumheller.

Pine Lake's drainage area is very large compared to its volume of water. This ratio alone would suggest a very fertile lake, because there is a large area of land to supply nutrients to a small body of water.

The Theoretical Phosphorus Supply table shows this. Slightly more than half of the land surrounding the lake has been cleared for agriculture or other uses. Since cleared land contributes about five times more phosphorus than does land in natural vegetation, the supply from the agricultural areas is theoretically very high.

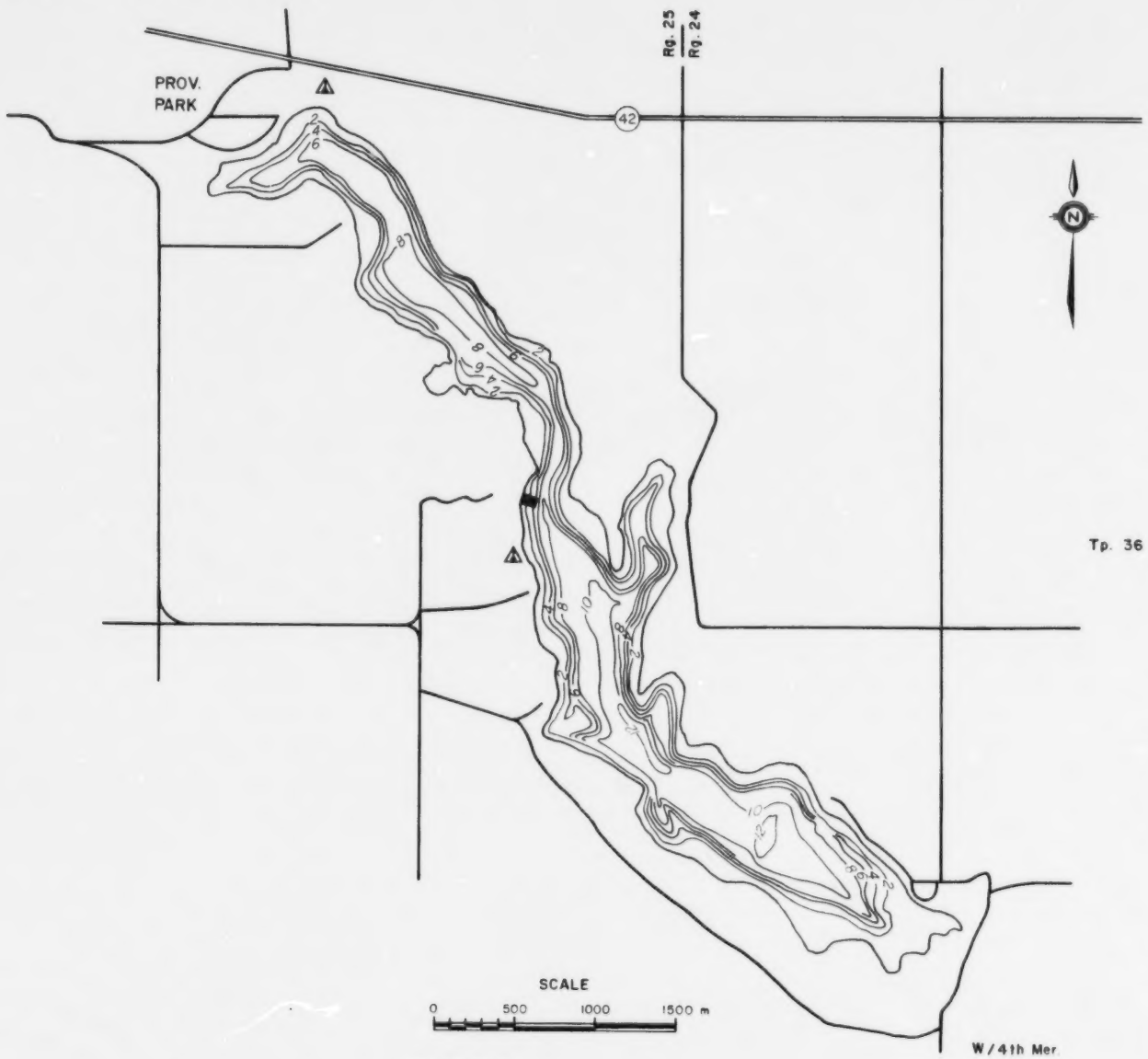
Because of the large drainage area and the extensive clearing, the areal loading figure is higher for Pine Lake than for almost any other lake studied in Alberta. This means that if you were to compare the supply of phosphorus to a square metre of Pine Lake with the supply to a square metre of Gull Lake or Sylvan Lake, Pine would be several times higher. In theory, Pine Lake should have very poor water quality indeed.

But anyone who has spent time on Pine Lake knows that in spite of occasional algal blooms, water quality in Pine Lake is fairly good. It would seem that the land area that actually contributes nutrients to the lake is over-estimated. For example, one small creek enters Pine Lake near the lake outlet. It is probable that nutrients entering the lake in this creek move directly to the outlet, so that this part of the drainage area is, in effect, excluded from interaction with the lake.

There may be other reasons why Pine Lake has better water quality than is predicted from its nutrient supply, but the study done in 1977-1979 was not designed to answer this question. It will have to remain unanswered until the lake is studied again.

The Theoretical Phosphorus Supply table shows that sewage from cottages and camps is a small percentage of the total phosphorus supply. Even if the supply from the watershed is over-estimated as mentioned above, this proportion would still be small compared with other sources.

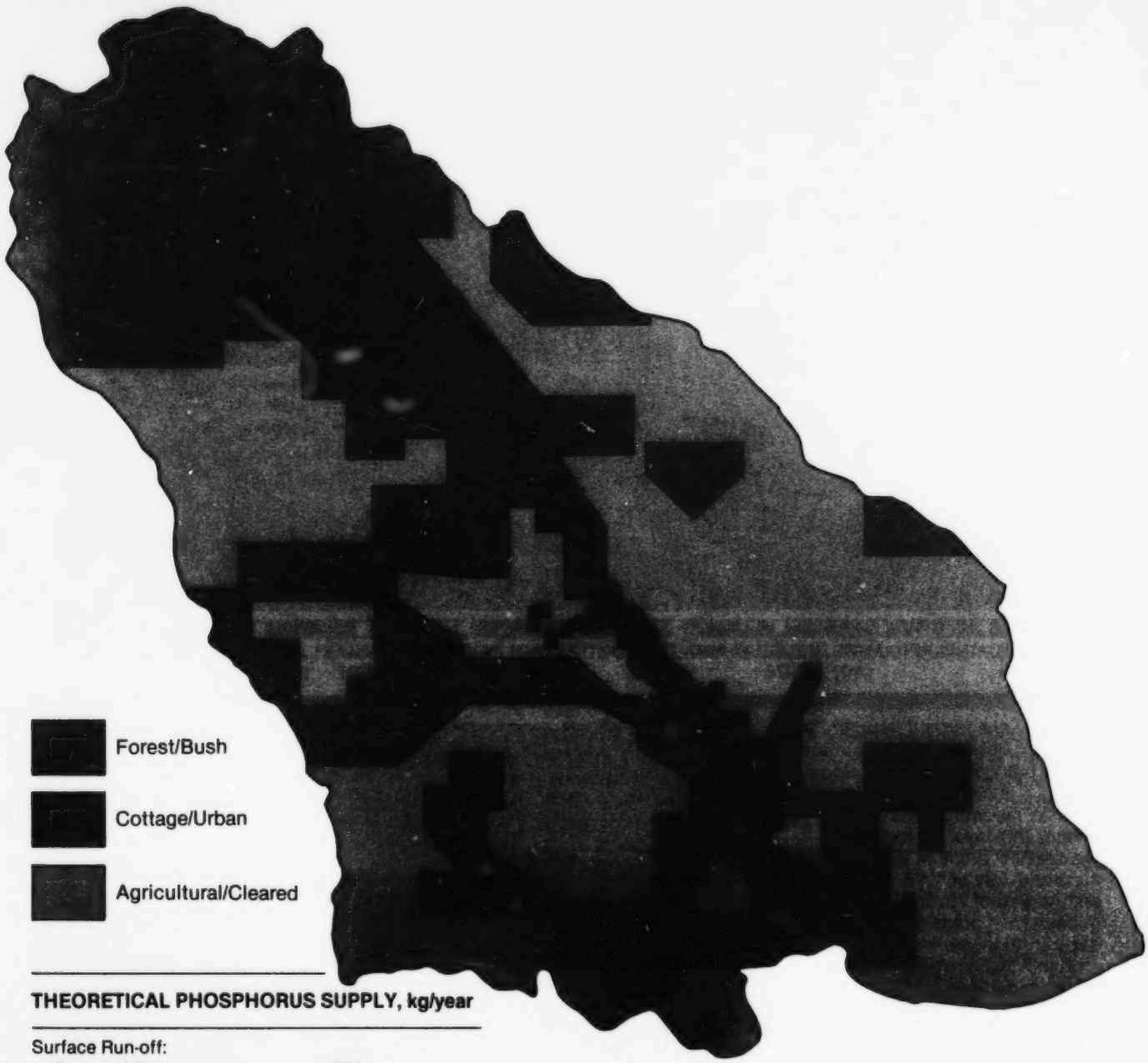
Depth Contour Map



PHYSICAL AND HYDROLOGICAL CHARACTERISTICS

SURFACE AREA	km^2	4.01
DRAINAGE AREA	km^2	156.
DRAINAGE AREA/ LAKE VOLUME		6.
MAXIMUM DEPTH	m	12.0
MEAN DEPTH	m	6.0
VOLUME	m^3	24.2×10^6
INFLOW	m^3	$5.4 \times 10.^6$
RESIDENCE TIME	years	4.4

Pine Lake
Watershed Map

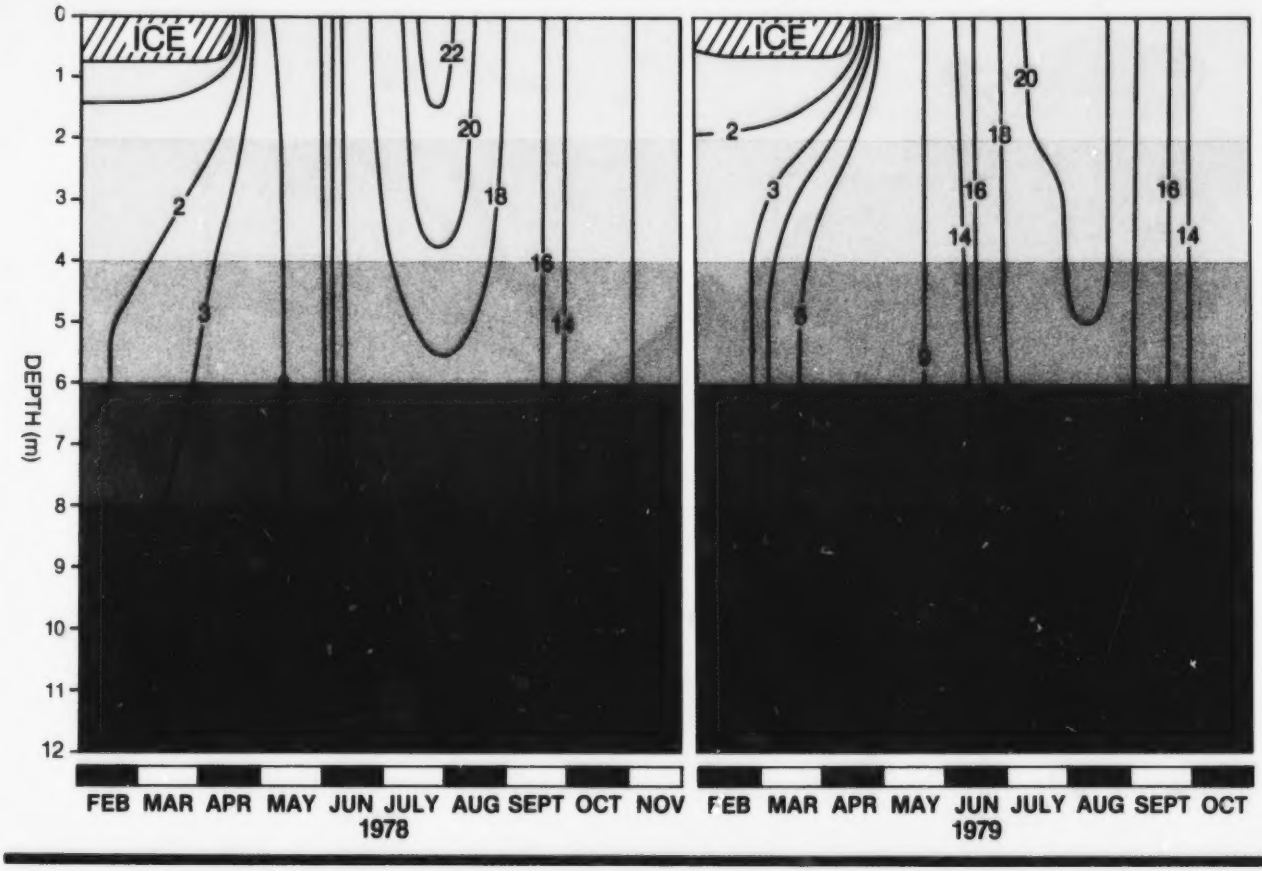


THEORETICAL PHOSPHORUS SUPPLY, kg/year

Surface Run-off:	
Forested/Bush	652.
Cleared/Agricultural	3,503.
Cottage/Urban	43
Sewage effluent from all cottages and camps	259.
Precipitation	122.
TOTAL	4,578.
Areal loading, g/m² of lake surface	1.15

0 1 2 3
km

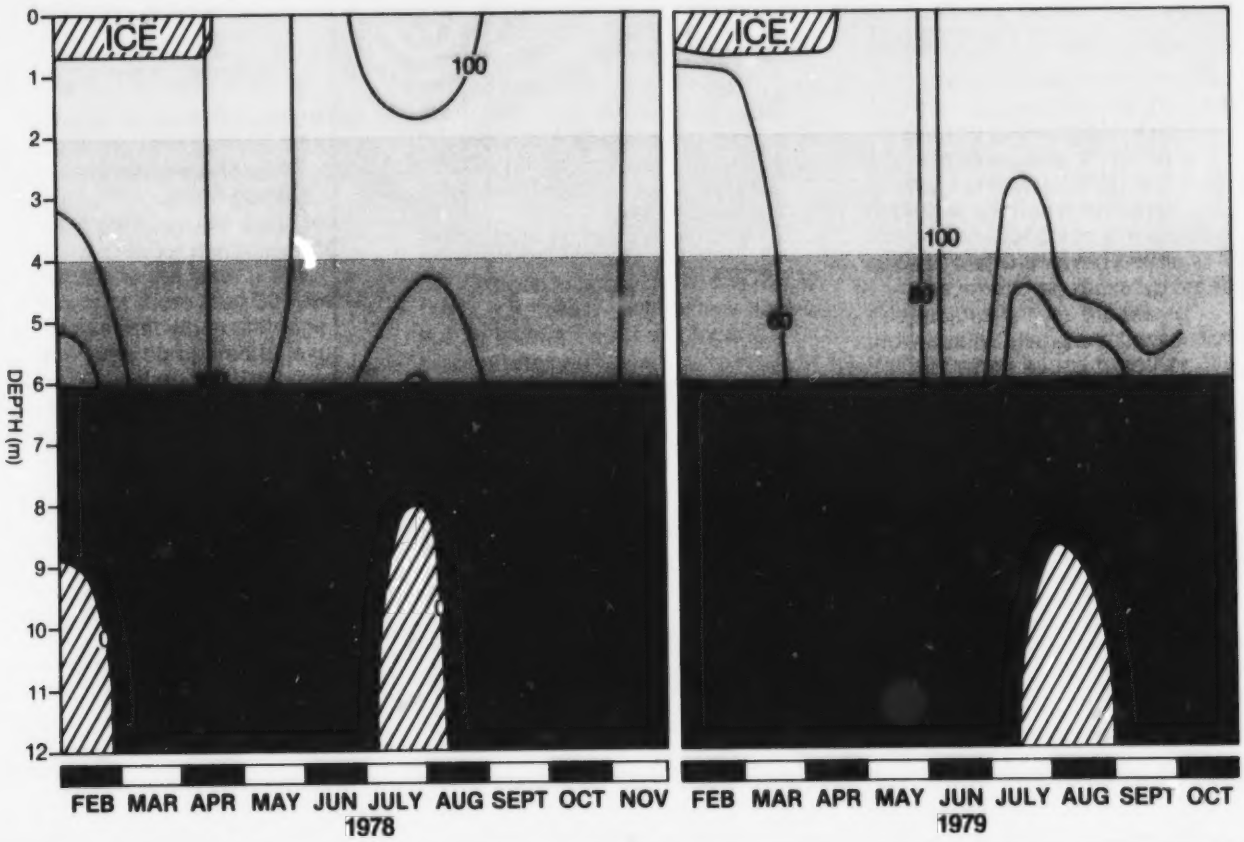
Temperature (°C)



Pine Lake formed temperature layers for only part of the summer during both years studied. Because of this, it is classified as a mixed lake. As the temperature graph shows, this layering took place in the deepest areas of the lake in June and July of 1978, and in July and August of 1979. But even in midsummer, areas that were as deep as 10 m were not layered. It is probable that the entire lake would mix in midsummer during strong winds. The vertical lines in spring and fall indicate mixing from top to bottom.

SEE "EXPLANATION OF LAKE CHARACTERISTICS" AT END OF BROCHURE FOR CLARIFICATION OF THESE GRAPHS.

Dissolved Oxygen (% Saturation)

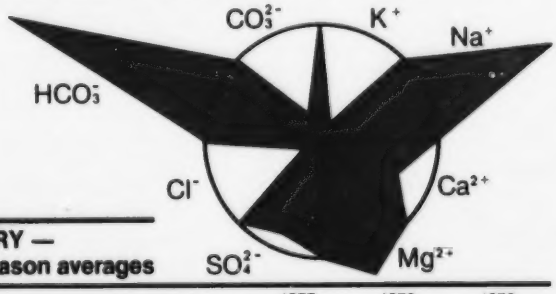


The dissolved oxygen graph shows that when the lake was strongly layered in midsummer, oxygen levels near the bottom fell to zero. Fish probably would not be found below 5 or 6 m during this time. During this time also, chemical changes related to low oxygen would allow phosphorus to move from the bottom mud to the water. When the lake mixed again, this phosphorus would supply growing algae, thus maintaining their population even when there was little nutrient supply from the watershed or from precipitation.

In winter, there was some oxygen depletion near the bottom, but there was sufficient oxygen in the upper half to support fish.

The ions of sodium (Na) and bicarbonate (HCO_3) dominate the water chemistry of Pine Lake. This is typical of a number of lakes in Alberta. Alkalinity, total dissolved solids, and pH are well within the ranges favorable to fish and other aquatic life. The slightly higher values for these characteristics in 1979 compared to 1978 is probably a result of lower rainfall and the concentrating effect of evaporating lake water.

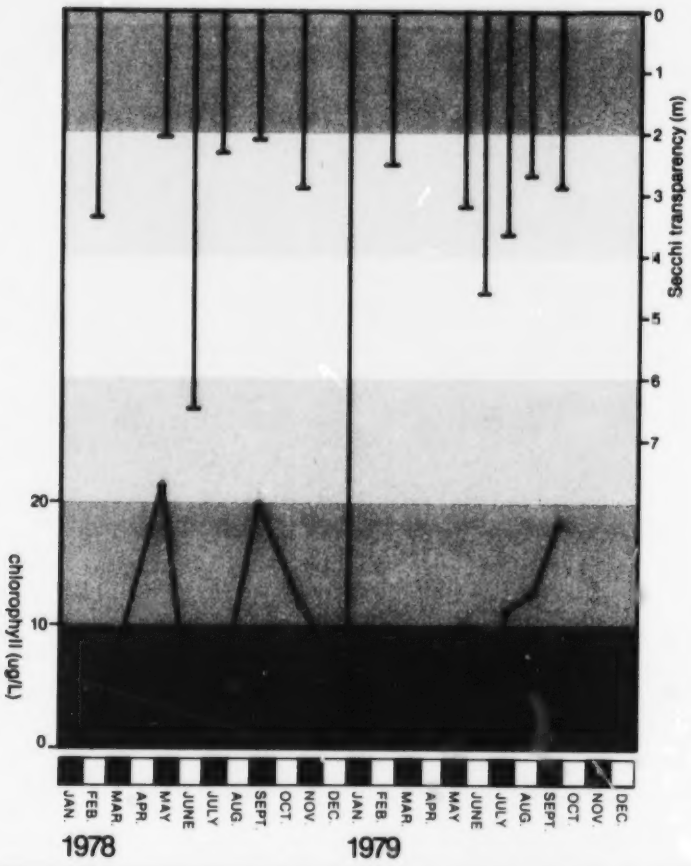
IONIC DIAGRAM —
Relative proportions of ions 1977, 1978 & 1979



CHEMISTRY —
ice-free season averages

		1977	1978	1979
TOTAL SALINITY	meq/L	14.	15.	15.
pH (range)		8.8	8.1 - 8.9	7.9 - 8.8
ALKALINITY	mg/L	271.	279.	299.
TOTAL DISSOLVED SOLIDS	mg/L	385.	392.	401.

Trophic Status



TROPHIC CHARACTERISTICS — ice-free season averages

		1977	1978	1979
PHOSPHORUS	µg/L	50.	49.	53.
NITROGEN	mg/L	1.51	1.61	1.37
CHLOROPHYLL	µg/L	—	11.	11.
SECCHI TRANSPARENCY	m	—	3.1	3.3

TOTAL NUMBERS OF BENTHIC ORGANISMS	7,343/m²
Oligochaeta	0% of total
Chironomidae	59% of total

Pine Lake is mildly eutrophic, with fairly clear water for much of the summer. As the trophic status graph shows, there was little algae (chlorophyll) in the water in June during both years studied, then populations built up to peaks in September.

The clarity of the water is related to its amount of algae. When populations were low in June of 1978, a person fishing on the lake might have seen the bottom in 5 m (15 feet) of water. Conversely, during the spring bloom in early May, a fisherman would have had a difficult time seeing the bottom in 2 m (6 feet) of water.

Blue-green algae were the most abundant type of algae during the chlorophyll peak in August and September both years. These can form scums or blooms that blow onto beaches. Although Pine Lake does produce these blooms occasionally, especially late in the season, they don't seem to occur every year with equal intensity.

A person driving a boat from the north end of Pine Lake to the south end might see clearer water toward the south. Although there is no statistical difference between the two ends, there is a tendency for chlorophyll to be higher at the north end. This is probably because much of the phosphorus supply from the watershed enters from the north (see watershed map).

Explanation of Lake Characteristics

PHYSICAL AND HYDROLOGICAL CHARACTERISTICS

Drainage Area or the watershed of a lake is the land surface from which a lake receives its water. As rain water or snowmelt gathers in streams, it picks up soil particles, nutrients and other materials and carries them to the lake.

A study of more than 30 Alberta lakes shows that when drainage areas are large compared to lake volumes, (i.e. when this **Drainage Area/Lake Volume** ratio is large), lakes have more algae (are more eutrophic) (see TROPHIC CHARACTERISTICS).

Mean Depth is the volume of the lake divided by the surface area. Shallow lakes are often more eutrophic than deeper lakes of a similar size.

Inflow is the total volume of water entering the lake in a year. It is related to **Residence Time,** which indicates the time it would take the inflow to completely fill an empty lake.

TEMPERATURE

Alberta lakes show two basic annual patterns of temperature distribution through the water.

Deep lakes, or those protected from strong winds, form layers with the coldest water near the bottom. Because this colder water is denser, it resists mixing into the warmer, lighter upper layer.

For much of the summer, the bottom portion of water is isolated from the top portion. In spring and fall, these lakes usually mix from top to bottom from wind action as the water becomes uniform in temperature and density. In winter, under ice, the warmest water (about 4°) is on the bottom, because water is most dense at this temperature.

Shallow lakes mix throughout the summer or layer only temporarily. In winter, the temperature pattern of these lakes is similar to that of deep lakes.

The diagram(s) show temperature at each depth over the annual cycle. Similar temperatures over time are connected by lines called isotherms. Vertical lines indicate mixing, while horizontal lines indicate layering.

DISSOLVED OXYGEN

Oxygen is essential to the life in lakes. It enters the lake water from the air through wind action, and plant photosynthesis.

Oxygen is consumed by respiration of animals and plants, including the decomposition of dead organisms by bacteria. A great deal can be learned about the "health" of a lake by studying its patterns and quantity of oxygen.

Lakes that are unproductive (oligotrophic) will have sufficient oxygen throughout the year at all depths. But as a lake becomes more eutrophic, and increasing quantities of plants and animals respire and decay, the balance shifts toward consumption — especially near the lake bottom where dead organisms accumulate.

In deep productive lakes (see TEMPERATURE), the oxygen in the isolated bottom layer may deplete rapidly, forcing fish to move into the upper layer (Fish are stressed when oxygen falls below about 20% saturation — shown in red on the diagram). Fish kills occur when decomposing or respiring algal populations use up the oxygen. In summer, this usually happens during an algal bloom on calm nights.

The diagram shows oxygen saturation at each depth over the annual cycle. Similar saturations over time are connected by lines called isopleths. Vertical lines indicate uniform saturation from top to bottom, while horizontal lines indicate stagnation near the bottom.

SALINITY AND TOTAL DISSOLVED SOLIDS

Lake water contains a multitude of dissolved substances. These can be seen by allowing a dish of lake water to evaporate. If the water is filtered to remove living organisms and other particles, and then allowed to evaporate, the residue is called **Total Dissolved Solids.**

The ions* that make up most of this residue can be measured individually, giving a value for **Total Salinity** when added together. The **Ionic Diagram** presents all of the major ions in a lake in proportion to each other.

Salinity is controlled by the types of rock or soil in the watershed and by the amount of evaporation relative to precipitation. Lakes of high salinity, such as many of those found in southeastern Alberta, have fewer species of plants and animals than freshwater lakes; many are too saline to support fish.

*Ions: Chemical form in water of constituents such as sodium and carbonate.

PH AND ALKALINITY

The pH of lake water refers to its concentration of hydrogen ions on a scale that runs from 0 (extremely acidic) to 14 (extremely alkaline). A pH of 7 is neutral — neither acidic nor alkaline.

Most Alberta lakes fall between pH 6 to 9, with the majority on the alkaline side. **Alkalinity** refers to the capacity of water to neutralize an acid, and is a measure of the alkaline materials present in the water.

Alberta lakes that were formed in sedimentary bedrock have a large capacity to neutralize acids entering them, such as from acid rain.

TROPHIC CHARACTERISTICS

The word "trophic" literally means nourishment.

Mountain lakes usually are "poorly nourished" or **oligotrophic.** Levels of nutrients such as phosphorus and nitrogen are low, plant life is sparse, and the water is clear. Fish production is low.

On the other end of the scale are well-nourished or fertile lakes called **eutrophic.** In these lakes, aquatic plants, including tiny suspended algae, flourish because the water contains abundant nutrients.

Mesotrophic lakes, those intermediate in fertility, often combine the best features of the other two types.

In some lakes, the nutrient supply is so high that plant growth inhibits the recreational use of the lake. Lake users consider such a lake to have poor water quality. One of the purposes in studying lakes is to determine whether fertility is increasing.

There are several ways to measure a lake's fertility or **Trophic Status.**

Phosphorus and **nitrogen** can be measured directly. Phosphorus in lakes of the Boreal Forest/ Parkland areas of Alberta range between 10 and 120 ug/L, or oligotrophic to highly eutrophic, and nitrogen ranges between 0.5 and 3.5 mg/L.

Transparency declines as a lake becomes more fertile. It is measured with a black and white plate called a **Secchi Disc,** which is lowered through the water on a line marked at metre intervals. The depth at which it can no longer be seen is the Secchi transparency.

The quantity of algae in the water can be determined by measuring its content of **Chlorophyll,** the green photosynthetic pigment.

The number of animals living in the bottom mud of the lake also may indicate its fertility. **Oligochaeta** are tiny worms; **Chironomidae** are immature stages of a fly called a midge.

THEORETICAL PHOSPHORUS SUPPLY

Lake scientists know that for most lakes, the amount of algae in the water is related directly to the amount of phosphorus. This is because phosphorus is usually in shortest supply of all the nutrients that lake plants need. When it runs out, the algal population can no longer increase. A larger phosphorus supply usually results in more algae.

Based on studies from all over North American, the quantity of phosphorus contributed by a hectare of forest is remarkably similar no matter where the lake is located. Similarly, agricultural or cleared land overlying sedimentary bedrock contributes fairly similar quantities of phosphorus per hectare in most lake watersheds. This was confirmed for Alberta by measuring quantities of phosphorus supplied by various land uses in the Baptiste Lake watershed.

In all studies, the phosphorus supply from cleared or agricultural land was greater than that from forest, averaging 5 times more.

The "theoretical" phosphorus supply is estimated, without actually measuring it, by multiplying phosphorus supply factors for each type of land use by the area of that land use.

Similar factors are used for the supply from precipitation. The supply from sewage assumes that all sewage enters the lake, since it is nearly impossible to measure this source in lakes. Therefore, the number reported represents the maximum possible supply from that source.

It might be expected that a large phosphorus supply would produce a eutrophic lake. But the size of the lake is also important. If the total phosphorus supply is divided by the surface area of the lake, the resulting **Areal Loading** figure can be compared with other lakes, and can be used as an indication of trophic status.